CASE STUDY- SUSTAINABLE TRANSPORTATION ENGINEERING: CREATING A SUSTAINABLE URBAN AREA: AN EFFICIENT TRANSPORTATION NETWORK

Abstract

For decades, transport has been seen as a connection to all aspects of life around the world. In such cases, the natural environment, social well-being, and economic development of the planet are usually Dependent on transportation networks.

In most cases, safe, clean, sustainable, and fair transportation systems allow countries, especially in cities and urban centers, to prosper. The aim of this paper is to improve the sustainability of a part of the city or a small town or towing. This report deals with the study of a network of the City of Bologna, Italy. The study focuses on the evaluation of the network, the area of the study area, also introduces some suggestions and solutions, that can improve the efficiency of the transit system. All analyses and guidance were based on the use of Openstreetmap (OSM) and SUMOPy tools that allowed the authors to produce the most reliable results. Artifacts are presented using a combination of graphical theory algorithms to obtain sustainable transportation using the example of a part of the City of Bologna, Italy.

Keywords : transportation networks; sustainable; transport policy; OSM; SUMOPy

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I. INTRODUCTION

The problem of the sustainability in transportation planning and re-organization is one of the most important aspect transportation engineering have to face off at the moment and of course in future visions.

The increasing people sensibility with environment problems and the depletion of fossil fuels should lead every new future project in a clear direction of planning, the most sustainable ones. Unfortunately, this is not always possible, cities are on the territory from a long time, but a lot still can be done to improve the sustainability of our transportations network, not only in bigger scale but also – and especially – on local scale, above all with an optimization of current transportation services and infrastructures.

In that point of view, we will study a small local portion of the network of Bologna, trying to make some operation to make more sustainable the study area.

II. STUDY AREA

The area is situated on the northwest side of the old town center with a very good connection with the inner city by public and private transport networks (fig. 1 & 2).
It is about **0.115 km²** with an average population density of **1.724,7 p/kmq**.

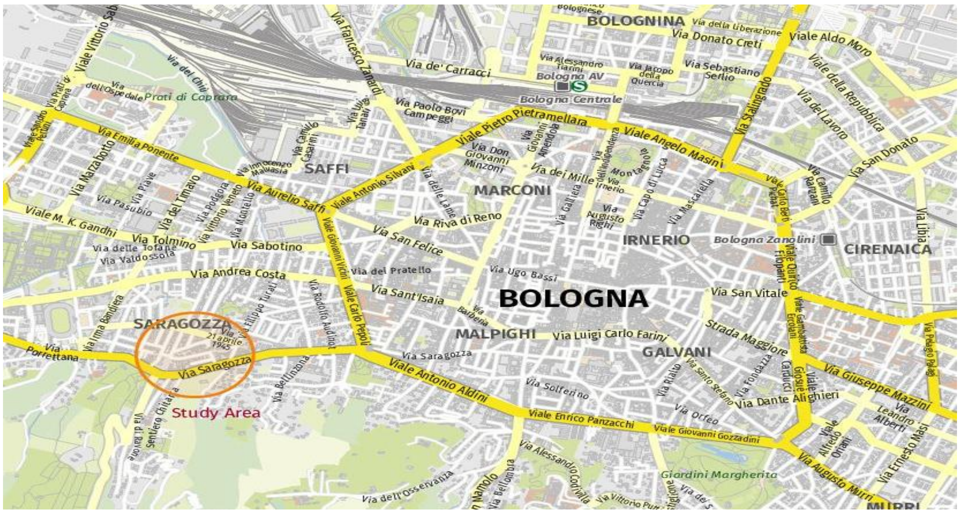

Figure 1: Study area position

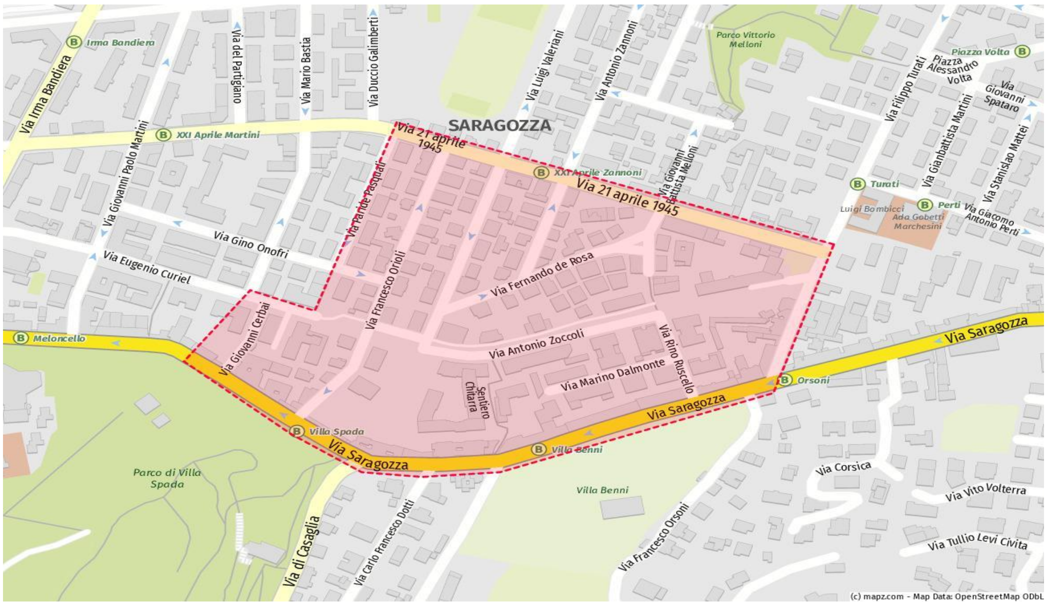

Figure 2: Study area, limits

It is a manly residential area with some supermarkets and other services like stores and churches that makes it almost self-sufficient and interesting in transportation point of view (fig. 3).

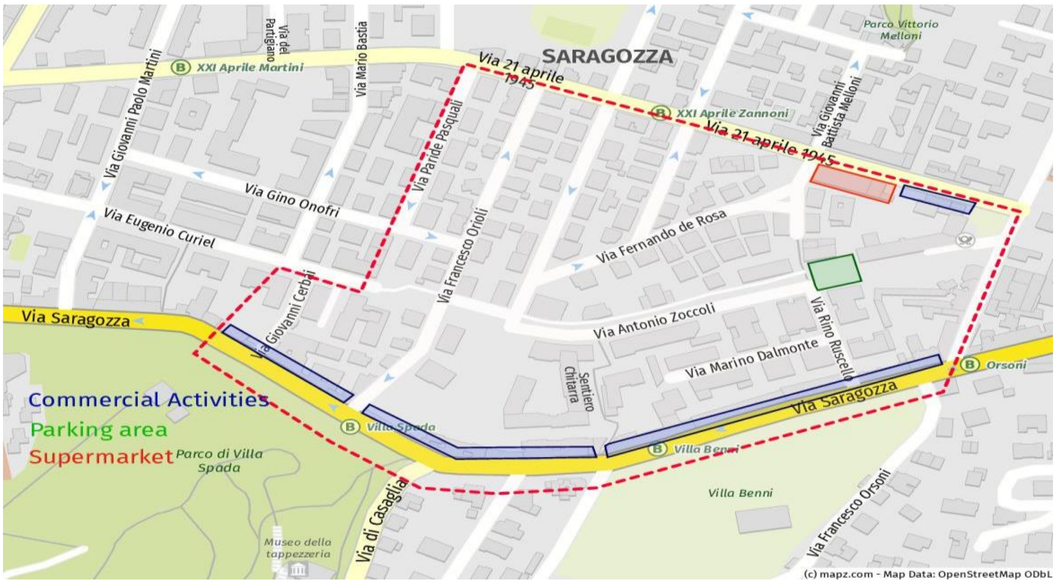

Figure: 3 Land use of the area

1. **Motivation of the study:** The area yet presents good transportation networks and links with some punctual problems we will try to solve. Pedestrian and cycling users are in most of cases protected with dedicated services but here again there are some missing/interrupted infrastructures points.

2. Assestment of Current Network

- **Maps of current network**

➢ **Private transport network**

Figure 4: Private transport network

➢ **Public transport network**

Figure 5: Public transport network

➢ **Cycling network**

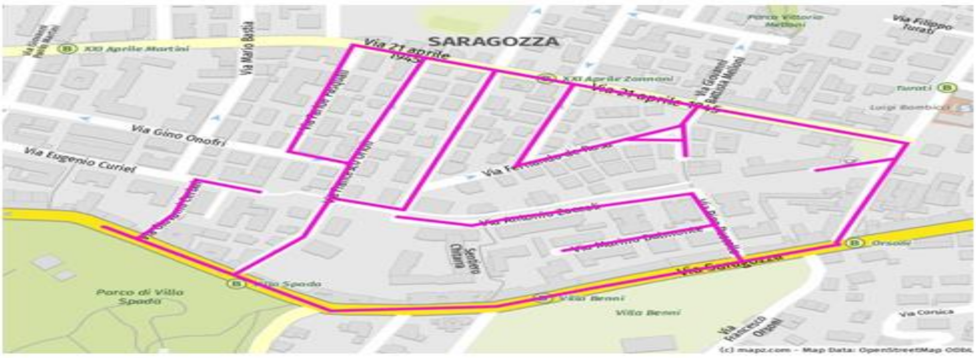

Figure 6: Cycling network

- **Footpath network**

Figure 7: Footpath network

- **Origins and destinations:** In this chapter we analyze the movements of bicycle mode that characterize the whole area. We are not going to create the O/D matrix but to recognize the principal paths people are now using to move from a point to another one using bike.

This study is based on the “desire line” consisting to individuate the air line that link an origin to a destination and then approximating this line as much as possible to the real network to see if it is possible for users travel with safety from an origin to a destination.The map below indicates witch routes are modeled on reserved paths and witch are not. We can see that in the, almost, whole parts of the area, the situation for using cycles is sufficient.

Figure 8: Usability of the area by bicycle.

The same study could be done for pedestrian network but the area is all covered by sidewalks and reserved footpath so we just considered the only local points where not present to make the interventions.

Traffic flows: Traffic flows (cars, bus, bikes and pedestrian) are taken on the most indicative links of the area in date 27/04/2021 from 07:30 AM to 08:30 AM. In figure.9 are showed. The intersection that origins the relative links.

Figure 9: Intersection used as reference

Zone(from)	1	1	1	3	3	3	4	4	4	5	5	6	6	6	6
Zone(to)	2	4	5	1	5	2	1	2	5	1	2	1	2	4	5
No.	16	23	6	122	245	221	9	45	39	11	86	26	5	35	6

Table1- OD Matrix – Car

Zone(from)	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
Zone(to)	2	3	4	5	1	3	4	5	1	2	4	5	1	2	3	5	1	2	3	4
No.	13	25	27	39	25	85	34	105	52	71	174	166	13	25	29	44	15	18	48	39

Table2- OD Matrix – Pedestrian

Zone(from)	1	1	1	3	3	3	3	4	4	4	5	5	6	6	6	6
Zone(to)	2	4	5	1	4	5	2	1	2	5	1	2	1	2	4	5
No.	9	5	13	45	19	55	133	4	15	8	11	36	11	6	29	14

Table3- OD Matrix – Bicycle

Zone(from)	2	3
Zone(to)	3	2
No.	14	13

Table4- OD Matrix – Bus

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3. **Blacklist:** The phenomenon of the blacklist is to identify the possible and visible damages or obstacles to the traffic flow, which of course considers both vehicle and pedestrian movements. Upon critical review, strategic measures are adopted and recommended as possible ways to reducing, combating the problem or improving the situation. The problems, which are present in the study area, have been divided in the following categories:

   - Infrastructure wrong use – Parking Problems
   - Unsafe cycling- Lack of cycle path
   - Sidewalk interruptions – Obstacles on the sidewalks
   - Garbage bins wrong position
   - Bicycle racks missing
   - Traffic jam caused by a bus stop
   - Roads' surface quality issues

   We have located some problems in the study area that may preclude the correctuse of the infrastructures or the safety of pedestrian and the cycling users.Here is the list and for the general view the blacklist tables have been added at the conclusion part.

   - **Infrastructure wrong use – parking problem (*Attachment I, ref. A*):** Reserved bus lane used as parking zone by residents in VIA SARAGOZZA (Fig. 10)

Figure 10

Figure 11

However, the people living in these buildings owns the authorization to park their cars in that position, just on the bus lane (Fig. 11).

   - **Unsafe cycling – Lack of cycle path (Attachment I, ref. B):** In VIA SARAGOZZA (Fig. 12 a, b) Unsafe cycling and in VIA ANDREA COSTA (Fig. 13 a, b) & in VIA IRMA BANDIERA (Fig. 14 a, b) cycle path is missing or interrupted.

Figure 12 a

Figure 12 b

Figure 13 a

Figure 13 b

Figure 14 a

Figure 14 b

- **Sidewalk interruptions – Obstacles on the sidewalks (Attachment I, ref. C):** Side walks missing or fragmentation in a lot of point in the area, especially in VIA PIETRO BUSACHHI (Fig. 15 a, b) and VIA MARIO BASTIA (Fig.15 c).



Figure 15 a **Figure 15 b** **Figure 15 c**

- **Garbage bins wrong position (Attachment I, ref. D):** Garbage bins are collocated on the roadway, producing the reduction of the width lane and the unsafe use of them by people in VIA SARAGOZZA (fig. 16 a,b). Some other garbage bins are on reserved car parking like in VIA MARIO BASTIA and VIA FRANCESCO ORIOLI


Figure.16a **Fig. 16 b**

- **Bicycle racks missing (Attachment I, ref. E):** Bicycle racks are missing in the whole area, except the one or two parking zones, that cause people are now leaving bicycle tied on trees, traffic signs and electric rods (see Figures 17, 18, 19).

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Figure.17

Figure 18

Figure 19

- **Traffic jam caused by a bus stop (Attachment I, ref. E):** A traffic conjunction may occur because of the Bus stopping position, which is very close to the traffic signals in the intersection.

Figure 20 a

Figure 20 b

Even such as long lines of cars blocking the way along the intersection as the traffic light switches and major found in VIA SARAGOZZA (Fig. 20 a and Fig. 20 b.)

- **Roads' surface quality issues:** The variation in quality along the road occurs on some intersections between different surfaces used in the same street. For instance, at the node intersection between VIA SARAGOZZA and VIA ANDREA COSTA as shown in following figures, variation of levelling between two surfaces caused occurrence of potholes with unnecessary overly designed speed pump that road may cause damages to the cars. See (Fig. 21, Fig. 22, Fig. 23 and Fig. 24)

Figure 21

Figure 22

Figure 23

Figure 24

4. **Critical Points:** We recognize some critical points that are in our opinion the biggest problems of the area, the ones that first of all needs to and can be solved, and they are:

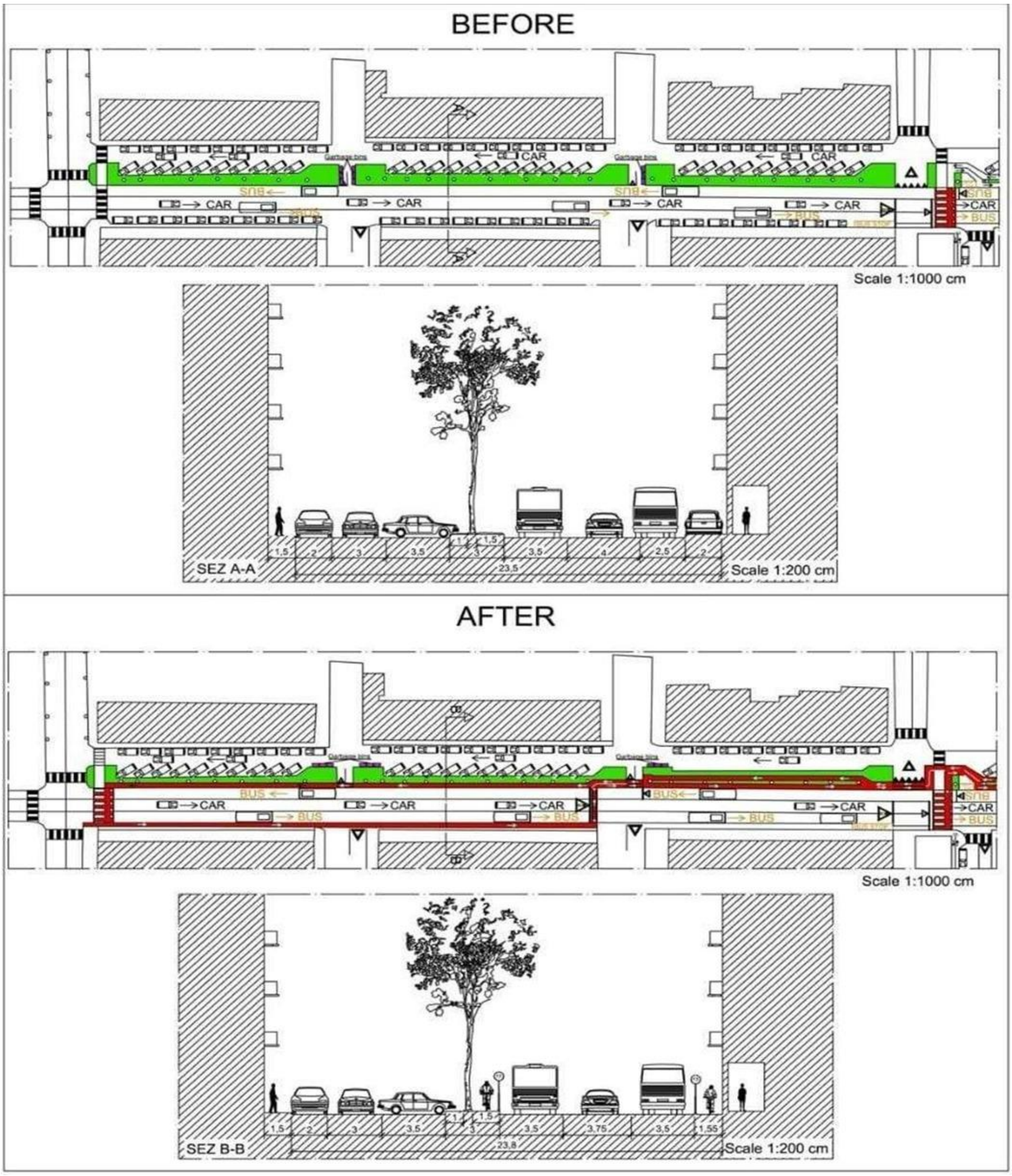
   Via Saragozza

We consider VIA SARAGOZZA a critical point that include different problems and not only one category: there is a wrong use of the reserved bus lane (see Fig. 11) that limits the capacity of the street, garbage bins are situated in an unsafe position on the lane (see Fig. 16 a & 16 b) and the cycle path is missing.

- **Cycle path/racks missing:** There are some interruptions of cycle paths that can be considered as links missing.Bicycle racks are missing but are needed to encourage people use cycle mode.

- **Garbage bins positioning:** Garbage bins are often not situated on best position.

5. Black spots and Necessary recommendations



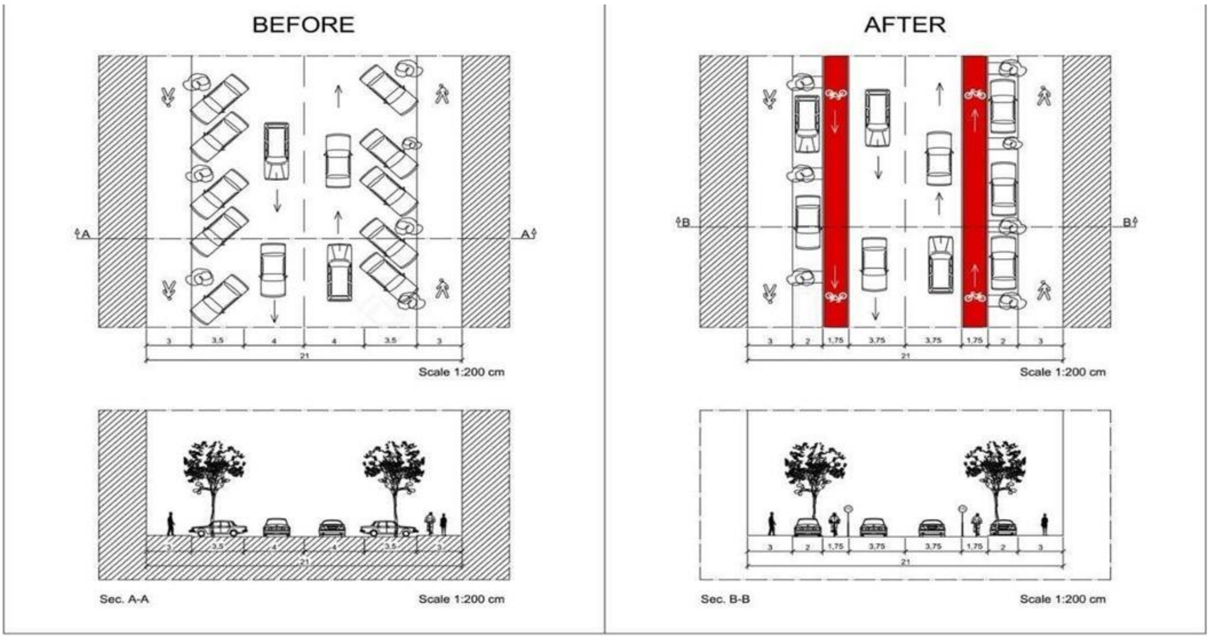


Table 5 B1: Lack of cycle path
VIA ANDREA COSTA

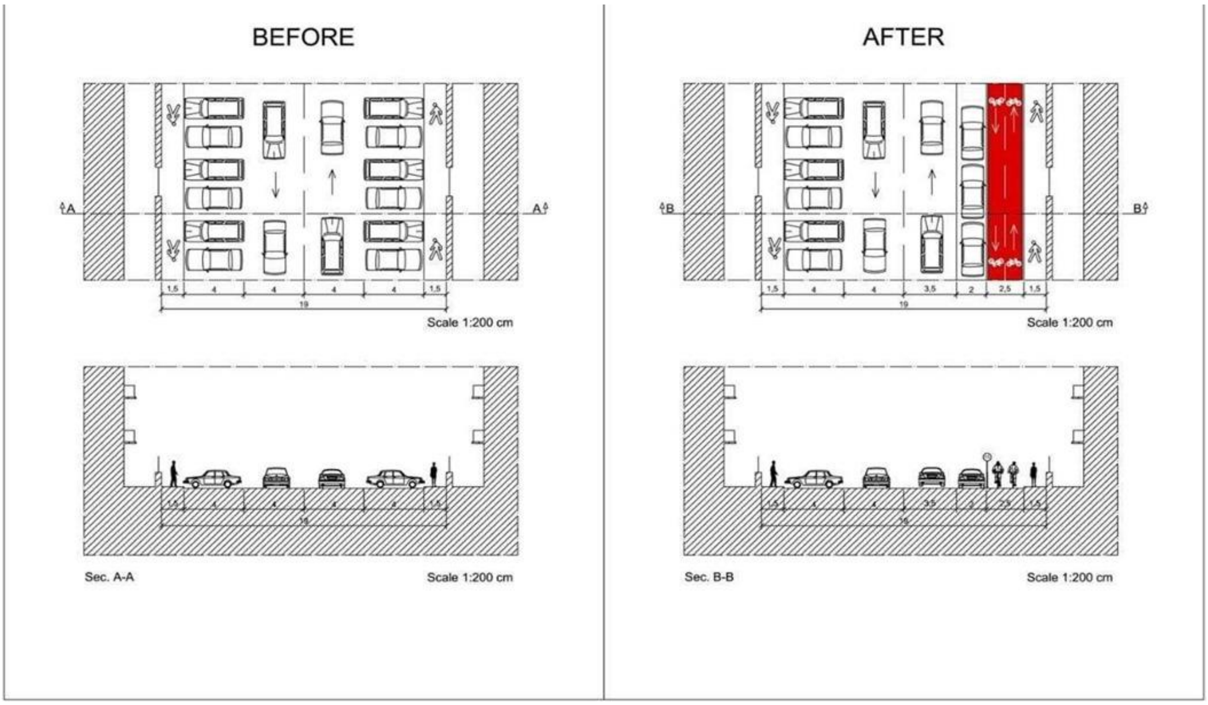


Table 6 B1: Lack of cycle path
VIA IRMA BANDIERA

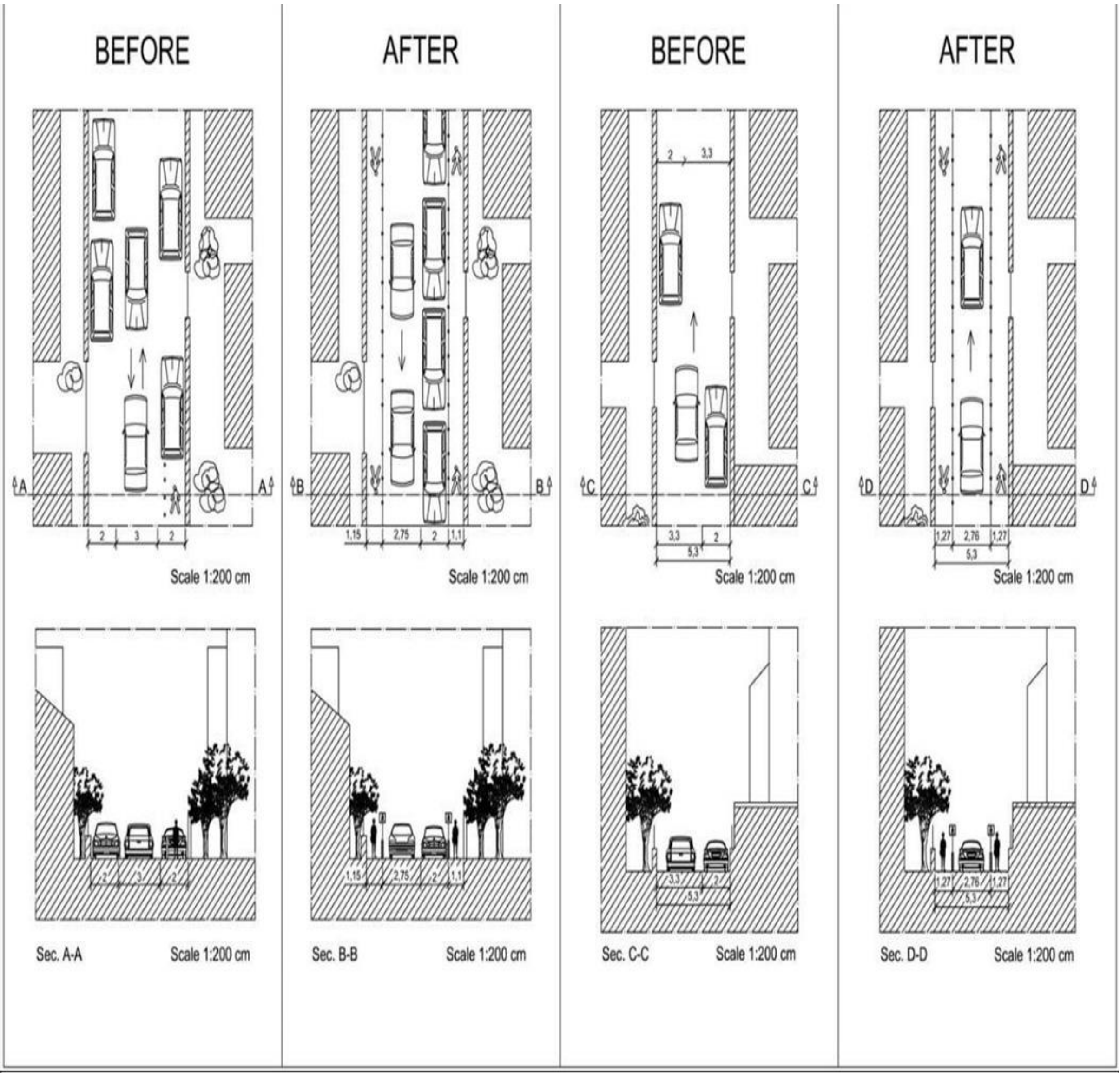


Table 7 C1-2: Interruption of sidewalk

C1: VIA PIETRO BUSACHHI C2: VIA MARIO BASTIA

III. NETWORK REDESIGN

1. **Redesigned maps:** Here are the new maps for a general view of the area after the interventions.

   - **New private transport network**

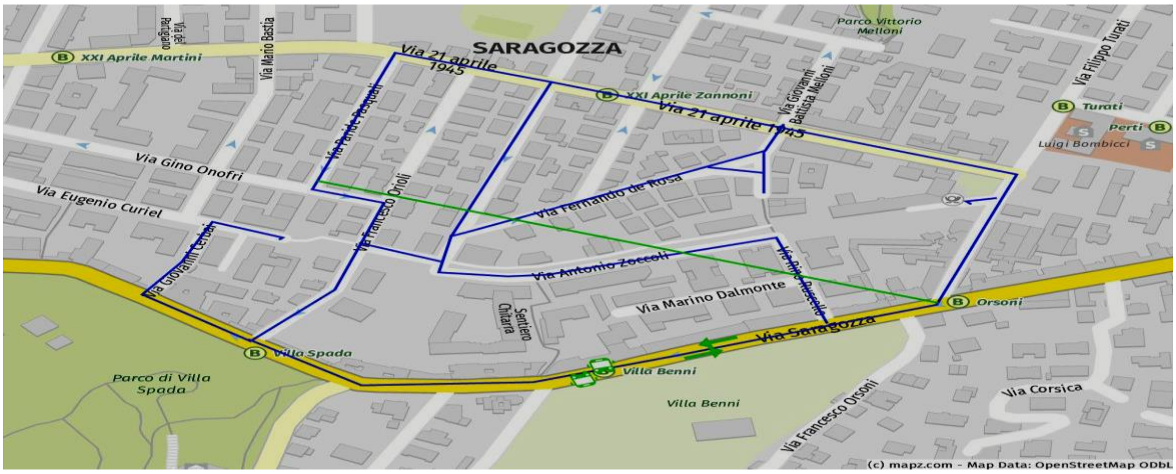


Figure 25: New private transport network, after interventions.

List of interventions

- **VIA SARAGOZZA (*Table I*)**

Problems solved

- ➢ Infrastructure wrong use – parking problems (see att. I, ref. A)
- ➢ Lack of cycle path (see att. I, ref. B-3)
- ➢ Garbage bins wrong position (see att. I, ref. D-1, D2)

Solutions

- ➢ Removal of parking alongside the street and lengthen of the reserved bus lane from 2.5 m to 3.5 m. Cars can be parked in Via Saragozza (Figure: 26).
- ➢ Addition of two mono directional cycle paths. On the lane directed from Via Filippo Turati to Via Oriolli it is used the green area of the traffic divider (width1.5 m). On the other side, in Via Saragozza, the cycle path is collocated along the bus lane by using the area achieved from the relocation of the parking zone. At the intersection with via this cycle path is rerouted alongside of the other, due to the bus stop near the intersection with Via Lercaro. Here it is inserted a cycle crossing and like all others ones it is protected with lightning signaling and red paint. This intervention makes possible the continuity of the cycle path.
- ➢ The garbage bins that now are shrinking the width lane of the intersections are relocated along the Via saragozza.

Figure 26: Parking relocation

- **VIA ANDREA COSTA (*Table II*)**

<u>Problem solved</u>

➢ Lack of cycle path (see att. I, ref. B1)

<u>Solution</u>

➢ Car parking alongside the lane is changed from an oblique disposition type to a linear disposition type (from 3.5 m to 2 m space used) and the lane width is reduced from 4 m to 3.75 m. the total space earned of 1.75 m is used to introduce two mono directional cycle path between the footpath and the parking.

- **VIA IRMA BANDIERA (*Table III*)**

<u>Problem solved</u>

➢ Lack of cycle path (see att. I, ref. B4)

<u>Solution</u>

➢ Insert of a bidirectional 2.5 m width cycle path in order to carry on thesegment yet present at the beginning of Via Turati the space is obtained changing the disposition of the parking along the lane from oblique (4 m) to linear (2 m) and reducing the lane width from 4 m to 3.75 m. The parking loss is compensated by parking areas now low used (Figure: 27).

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Figure 27: Car parking in the area

- **VIA PIETRO BUSACHHI (*Table IV*)**

<u>Problem solved</u>

- ➢ Lack of footpath (see att. I, ref. C1)

<u>Solution</u>

- ➢ VIA PIETRO BUSACHHI is a mainly residential local street with no commercial activities or service. With the intervention the traffic flow is limited only to one direction, from Via Bastia to VIA PIETRO BUSACHHI changing the bidirectional street to mono directional and making possible parking only on one side. In addition, the lane is restricted to 2.75 m; this makes possible adding two footpaths on both side of the street protected with pickets to prevent cars invasions or stops.

- **VIA MARIO BASTIA (*Table IV*)**

<u>Problem solved</u>

- ➢ Lack of footpath (see att. I, ref. C2)

<u>Solution</u>

- ➢ Addition of two footpath on both sides protected with pickets using space earned from the prohibition to park on both side of the street. This is compensated by the others parking area in proximity (see figure: 27).

- **Cycle racks additions**

Problem solved

- ➢ Absence of cycle racks (see att. I, ref.E)

Solution

- ➢ Addition of cycle racks near the bus stops to support intermodal transport.

Figure 28: Sample new bicycle racks to be installed.

IV. ORIGIN-DESTINATION MATRIX

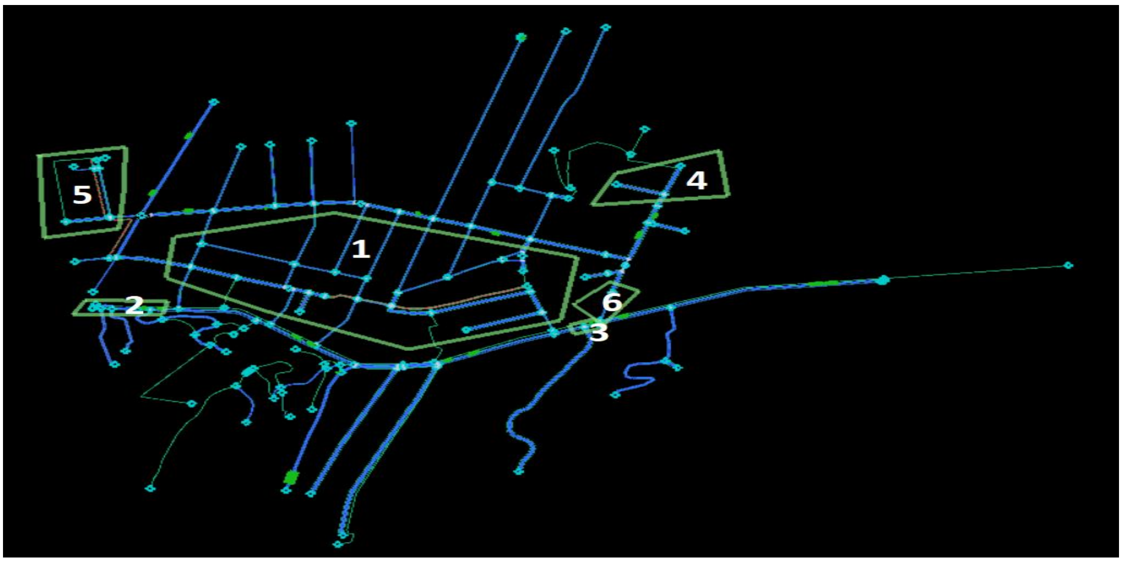

Figure 29: Representation of Zones

Where:
1 = Study Area (TAZ)
2 = External Zone (Southwest)
3 = External Zone (Southeast)
4 = External Zone (Northeast)
5 = External Zone (Northwest)
6 = External Zone (Southeast)

Shown in figure above is the study area for the project. The study area was divided into six zones: one zone for study area; and five external zones.

Based on the conducted traffic counts survey, a total of 1675 vehicles/hr. were counted entering the study area and a total of 922 vehicles/hr. were counted exiting the study area. This will be aggregated to 10% of vehicles will be coming and going to the study area, respectively. The remaining 90% will be then distributed to between the in-coming and out-going links. Four (4) classification of vehicles were counted during the peak-hour survey. Table 1, 2, 3, 4 mentioned above, shows the OD Matrix for all vehicles. This matrix was aggregated into four (4) different classification of vehicles which will be used for the scenario.

1. Proposed Intervention

- A vehicle reduction scheme can be considered such as implementing a WINDOW HOUR WITH RESTRICTION OF SPEEDS AND ROUTE DIVERSION to all the heavy vehicles to traverse the roads prohibiting them to enter during peak hour by Incorporating dedicated separate speed lane and restricted access to the pedestrians, Public and Private Vehicle.
- Improving the traffic signal cycle can also be another option to improve the traffic flow.
- PROMOTING of GREEN TRANSPORTATION by reducing of traveling by car up to 10 % and increased travelling by Bicycle at least up to 10% by keeping the total nos. of vehicle same within the study area.
- PROPOSING NEW BYPASS FLYOVER with the restricted access and speed (50 Km/ Hr.)

2. **Baseline Scenario:** Baseline Scenario was simulated based on the existing condition of the study area. Existing road networks was used for the simulation as well as the traffic counts gathered during the survey.

   It is necessary that the baseline simulation will depict with the real-world scenario of the study area. Roads must not be designed exclusively to a certain sector of users only. A complete street ensures that there are enough facilities for non-/motorized vehicles, pedestrians, PWD (person with disability), and other road users.

   Table 1-4 shows the number of vehicles entered in the study area .Based on this figure, majority of vehicles are in the VIA SARAGOZZA corridor.

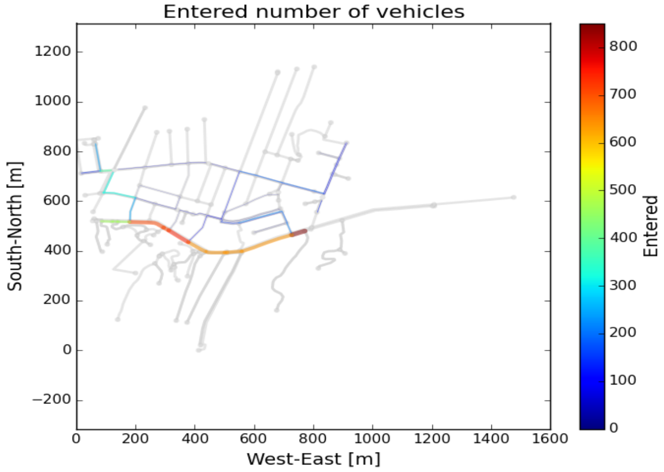

Figure 30: Entered number of vehicles.

Meanwhile, Figure 31 shows the average travel time along edges in the study area. It may be observed that longer waiting time can be seen at the signalized intersection before approaching Via Saragozza.

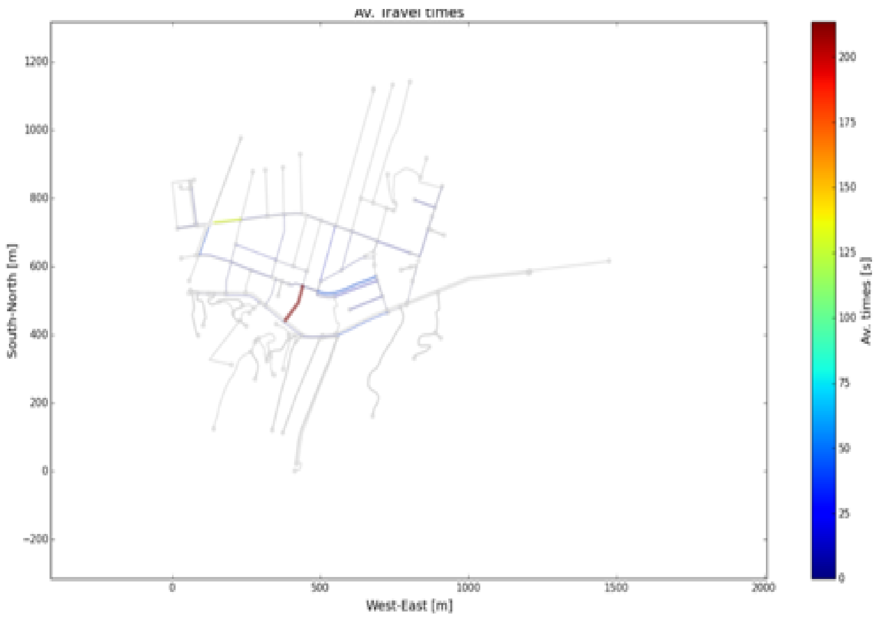

Figure 31: Average travel times of vehicles

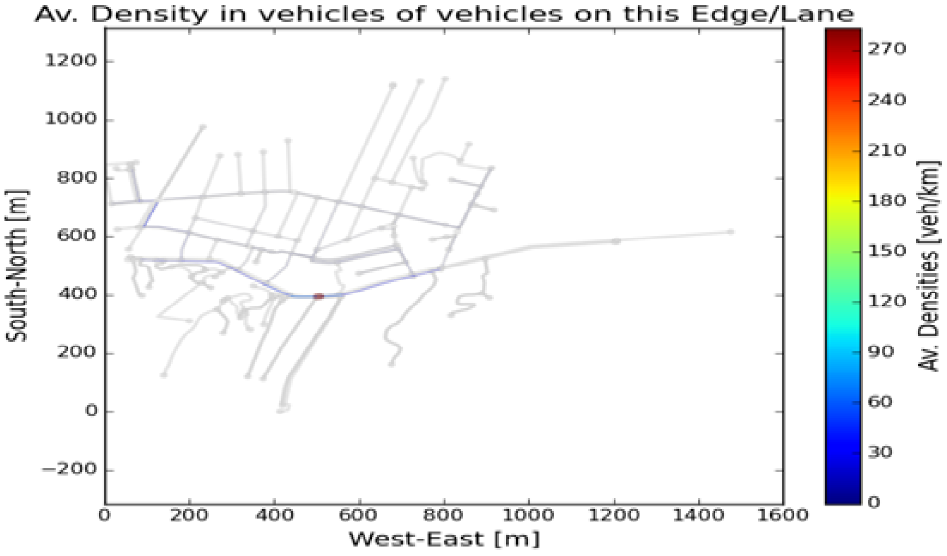

Figure 32: Average Density in vehicles of vehicles

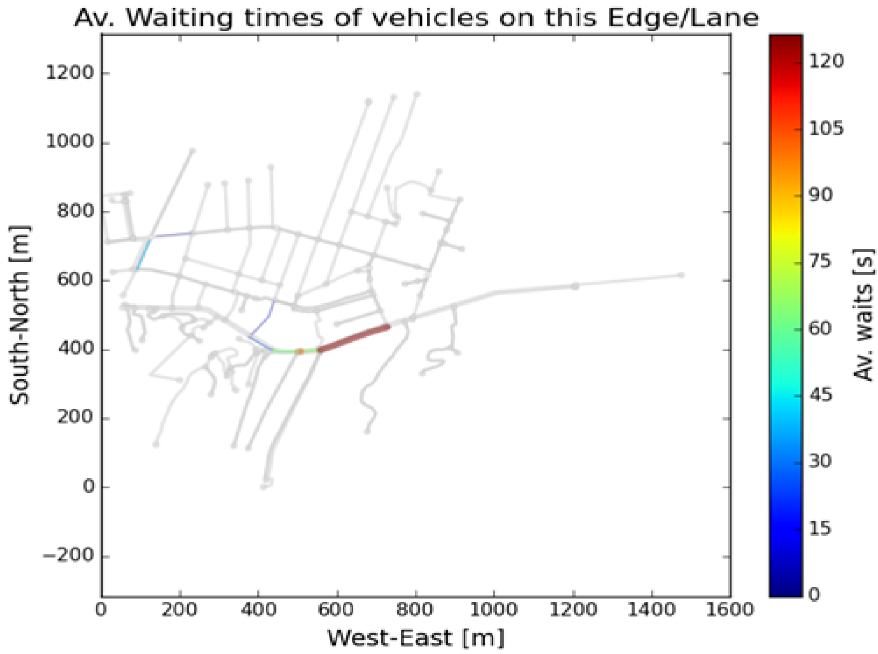

Figure 33: Average waiting time of vehicle

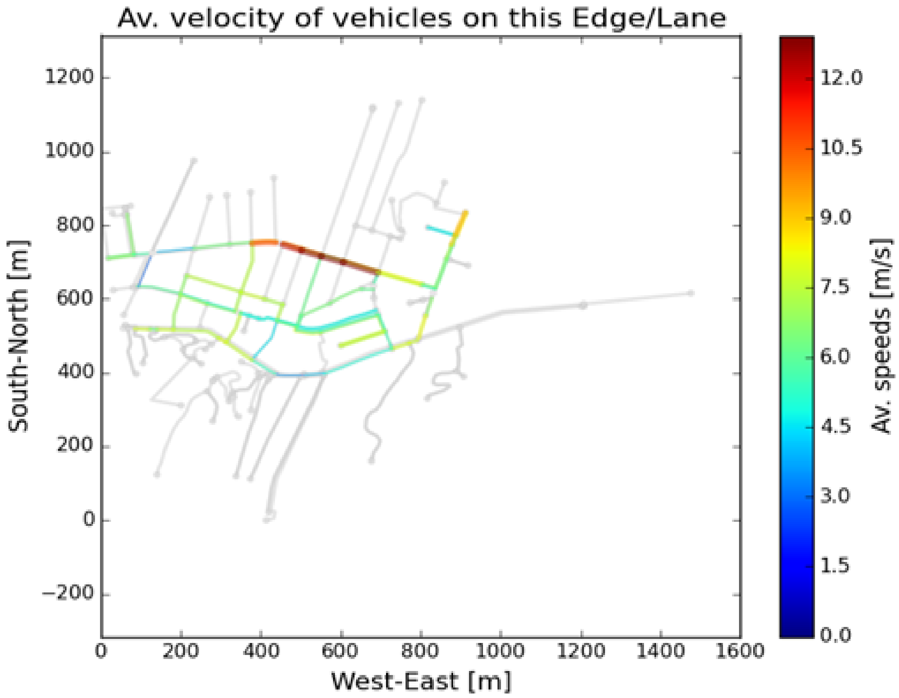

Figure 34: Average velocity of vehicles

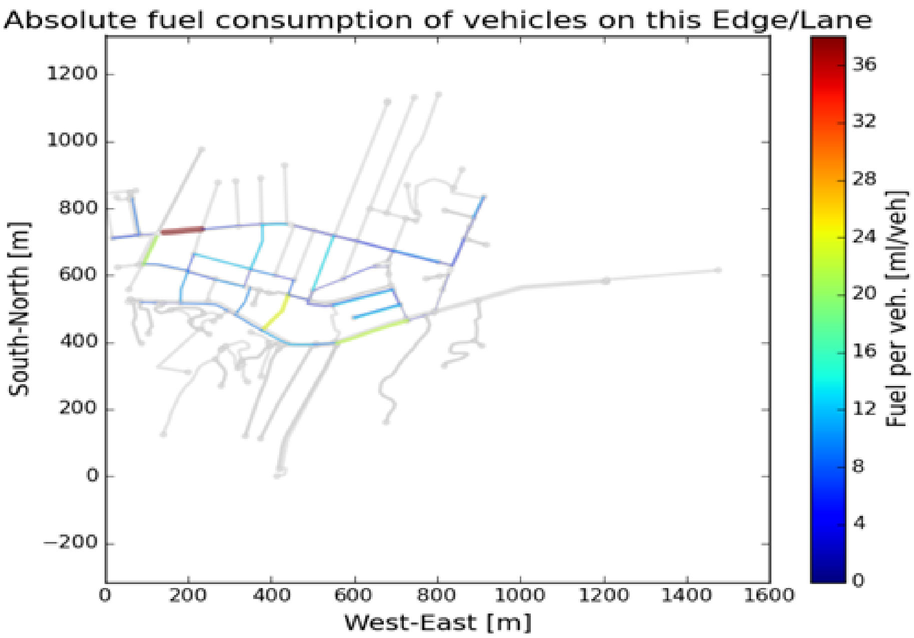

Figure 35: Average fuel consumption of vehicle

Vehicle noise was evaluated as well during the baseline simulation. These huge numbers are due to the high volume of motorized vehicle traversing the corridor. In connection to that, CO2 emission was evaluated as well as shown in Figure 38.

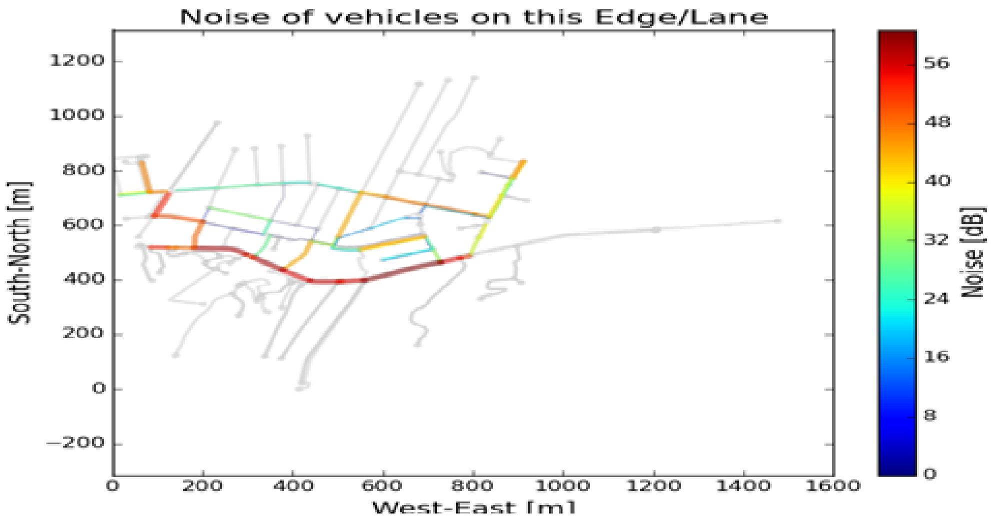

Figure 36 a: Noise of vehicles

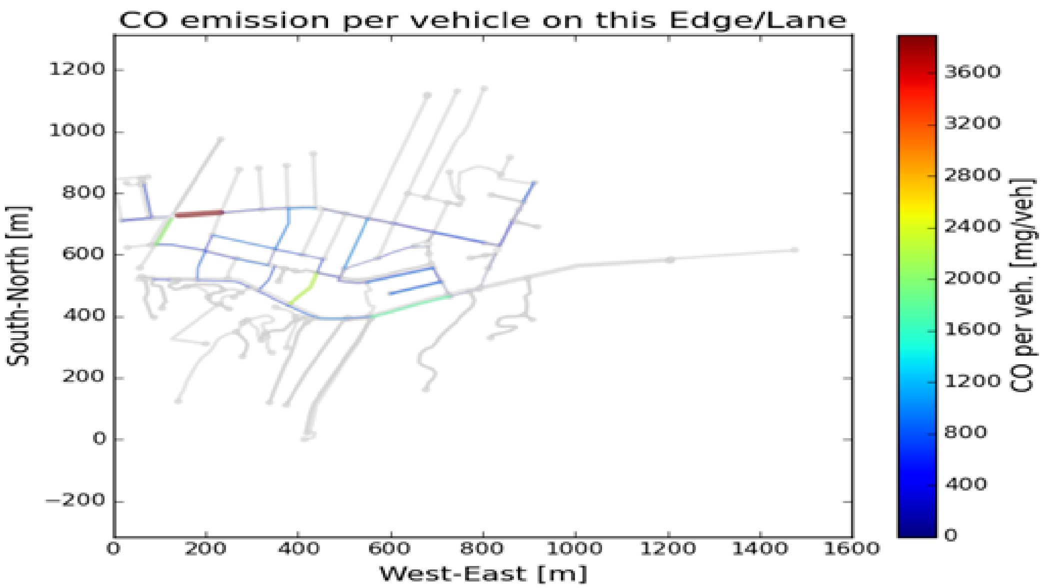

Figure 36 b: CO emission per vehicle

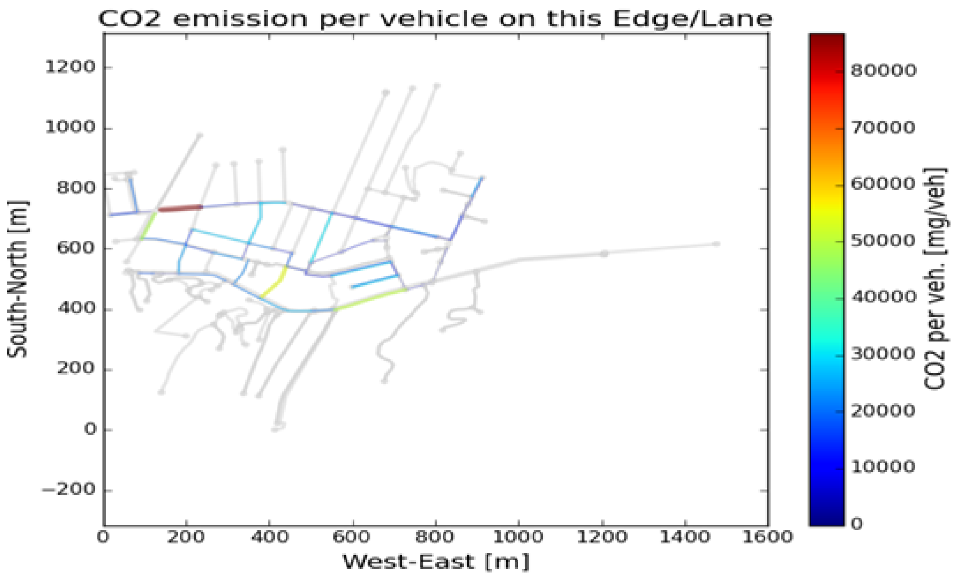

Figure 37: CO2 emission per vehicle

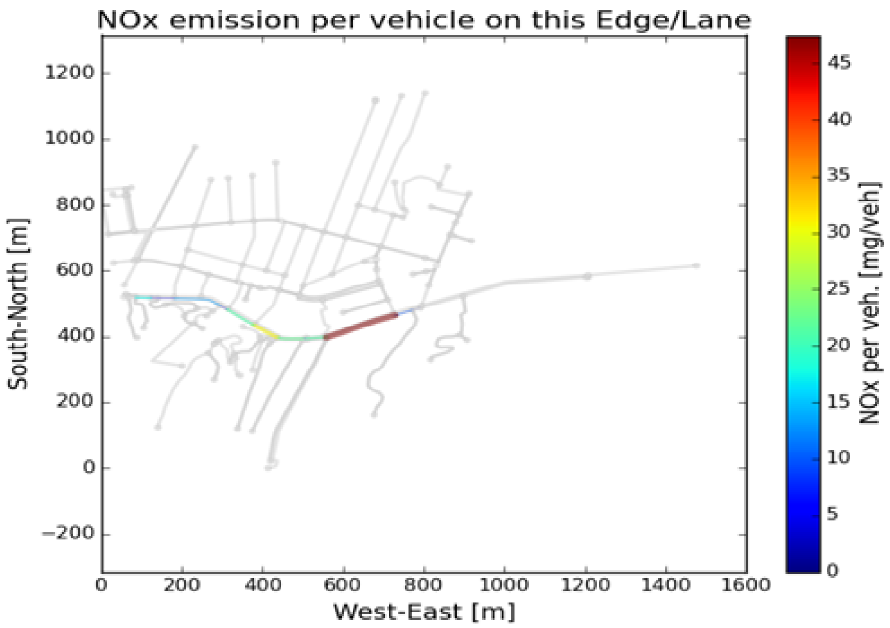

Figure 38: NOx emission per vehicle

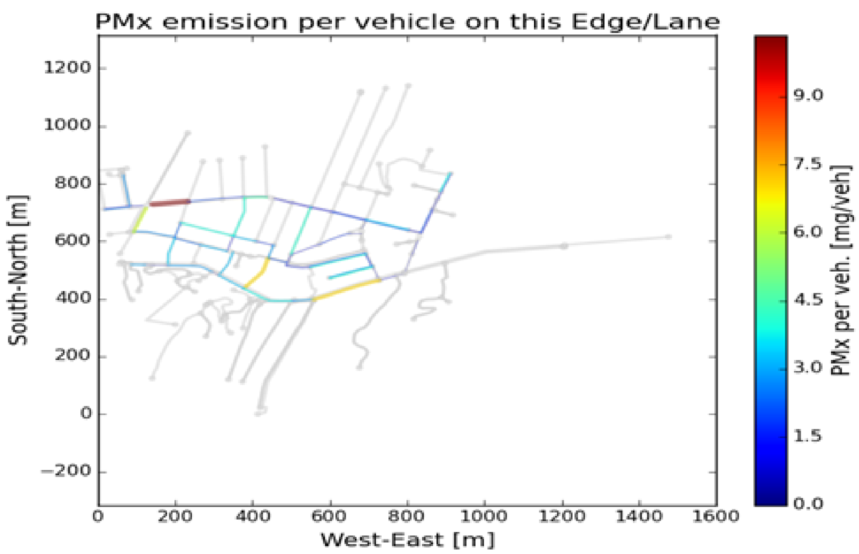

Figure 39: PMx emission per vehicle

With all these results, the group aims to improve the performance of the road network by decreasing the magnitude of these parameters. Thus, the group came up with the intervention presented in the previous section.

3. **Future Scenario:** To achieve the desired goals and objectives set by the group, the following proposals were made as per the seriatim, -

Table 8: Action Plan

OBJECTIVES	ACTION TAKEN IN TRAFFIC MODEL
WINDOW HOUR WITH RESTRICTION OF SPEEDS AND ROUTE DIVERSION	Incorporated dedicated separate speed lane and restricted access for the pedestrians, Public and Private Vehicle)
PROMOTE GREEN TRANSPORTATION	Reduction of traveling by car up to 10 % and increased travelling by Bicycle at least up to 10% by keeping the total nos. of vehicle same within the study area
PROPOSING NEW BYPASS FLYOVER	Proposed a separate Bypass Flyover with the restricted access (ref. Fig. 40 & 41) and speed (50 Km/ Hr.)

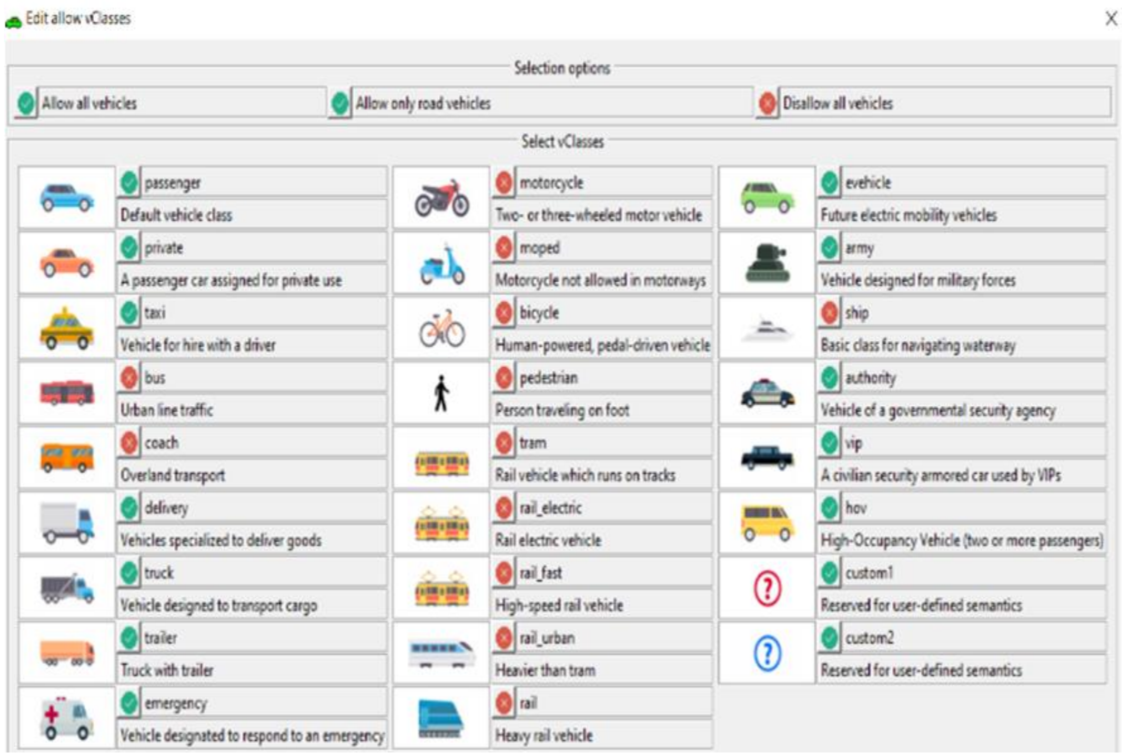

Figure 40

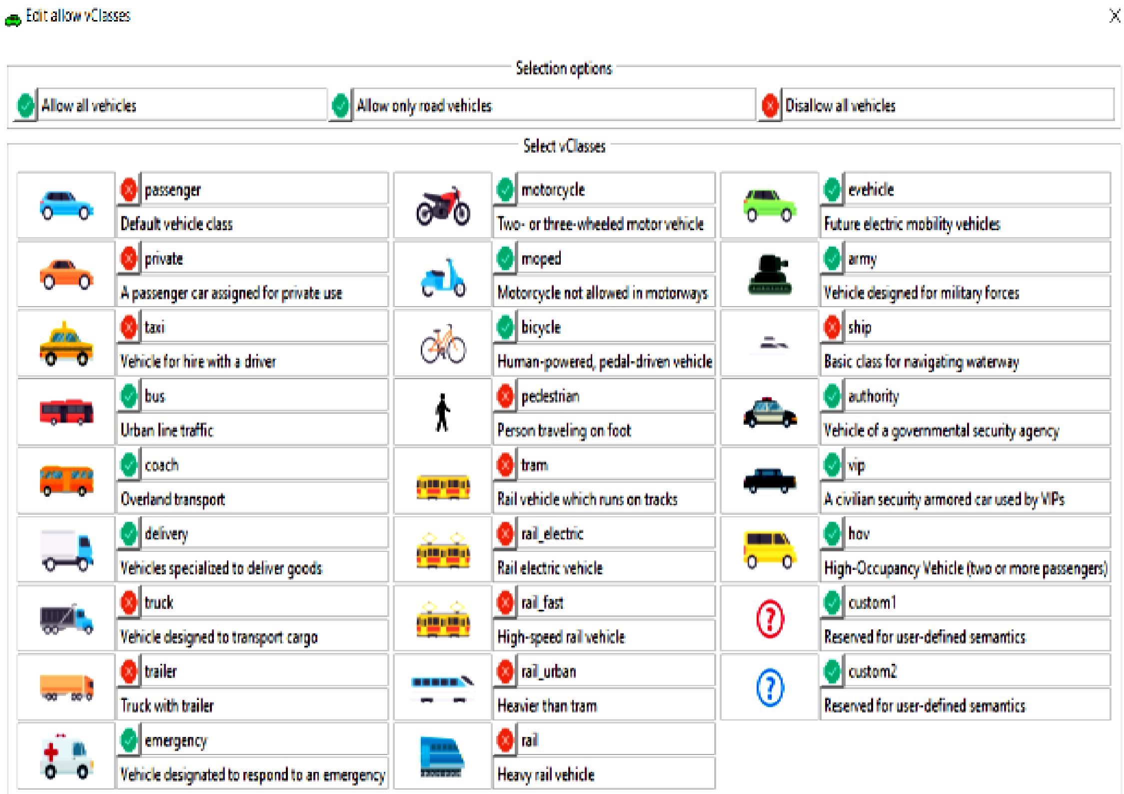

Figure 41

- **Edge data for window hour with restriction of speeds and route diversion:**

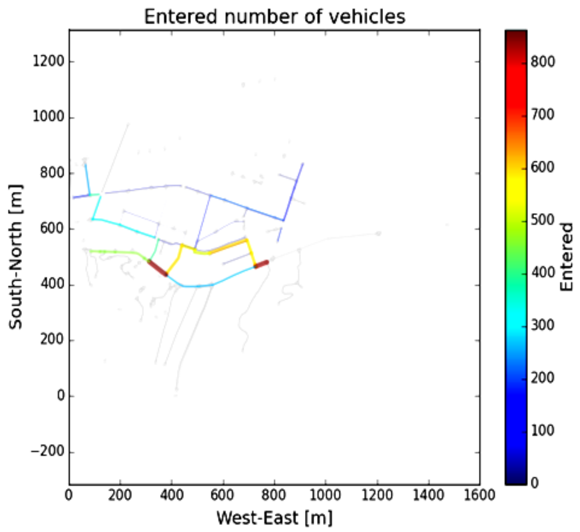

Figure 42: Entered no. of vehicles

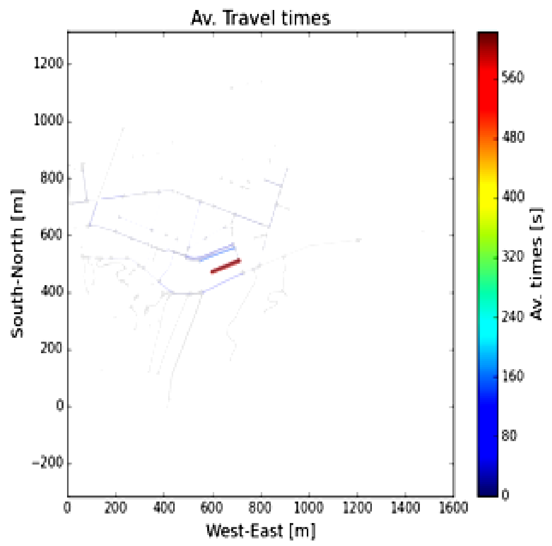

Figure 43: Av. Travel times

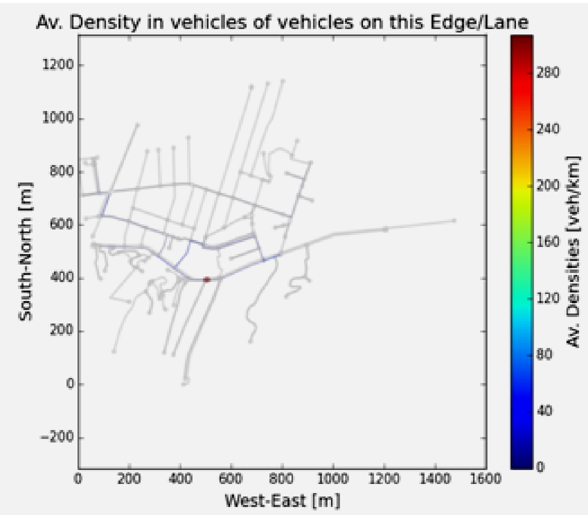

Fig. 44: Density in vehicle of vehicles edge/lane

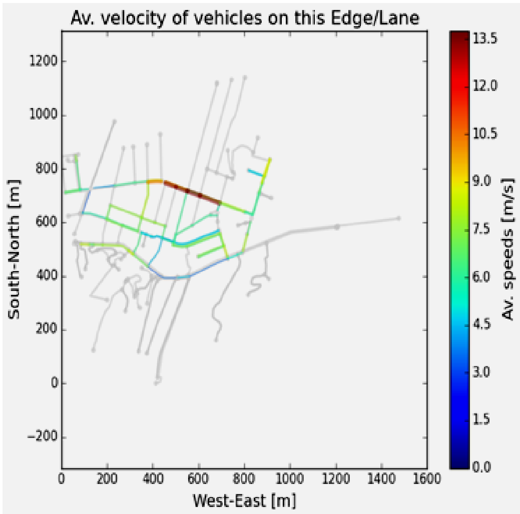

Figure 45: Av. velocity of vehicle on this on this edge/lane

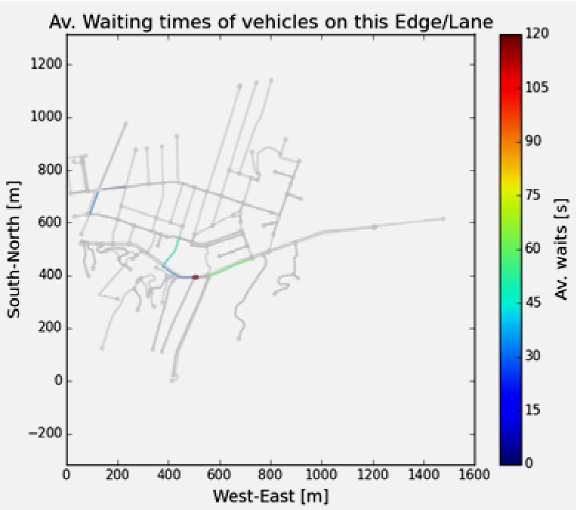

Figure 46: Av waiting times of vehicle on this edge/ lane

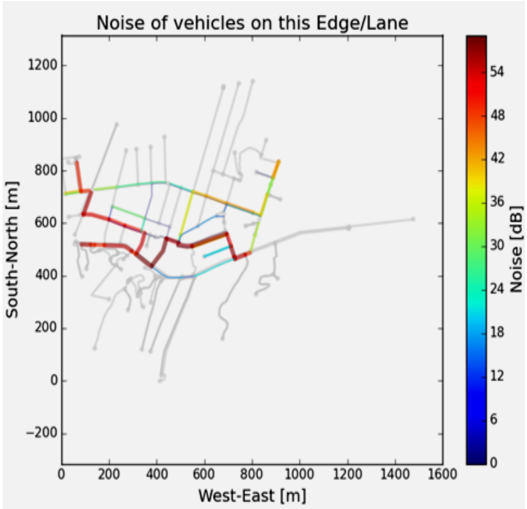

Figure 47: Noise of vehicle on this edge/ lane

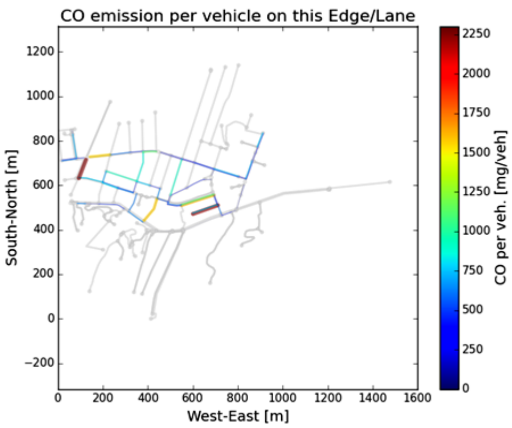

Figure 48: CO emission per vehicle on this edge/lane

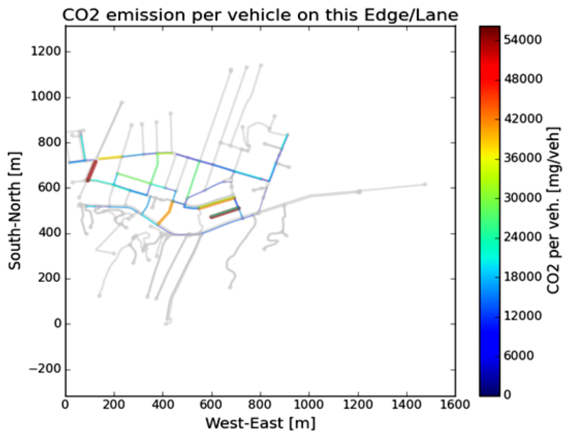

Figure 49: CO2 emission per vehicle on this edge/lane

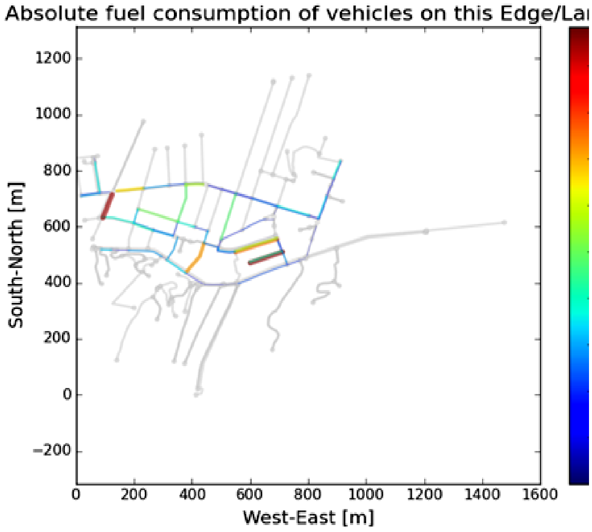

Figure 50: Absolute fuel consumption of vehicle on edge/lane

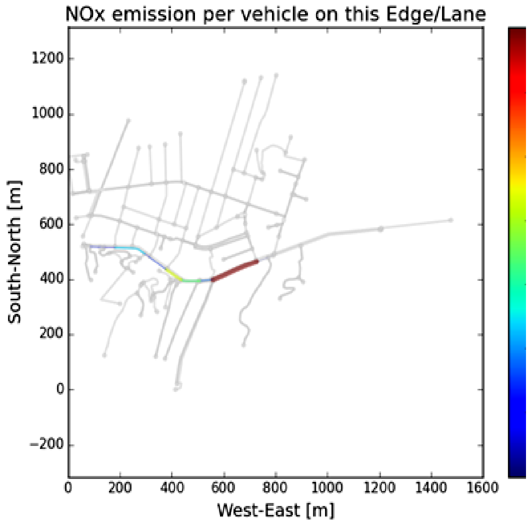

Figure 51: NOx emission per vehicle on this edge/lane

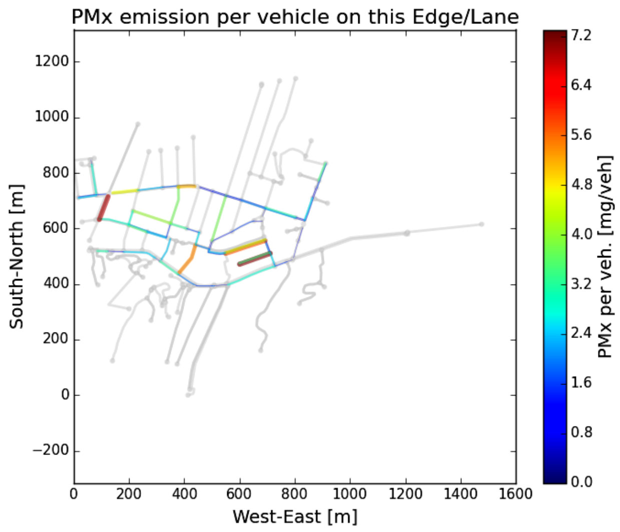

Figure 52: PMx emission per vehicle on this edge/lane

- **Edge data for promote green transportation**

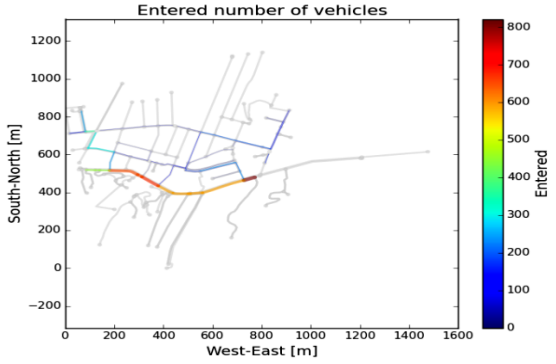

Figure 53: Entered no. of vehicles

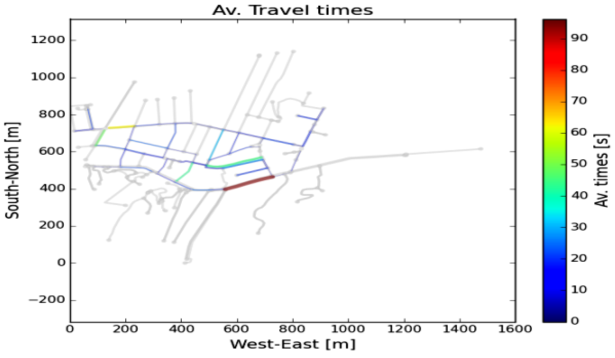

Figure 54: Av. Travel times

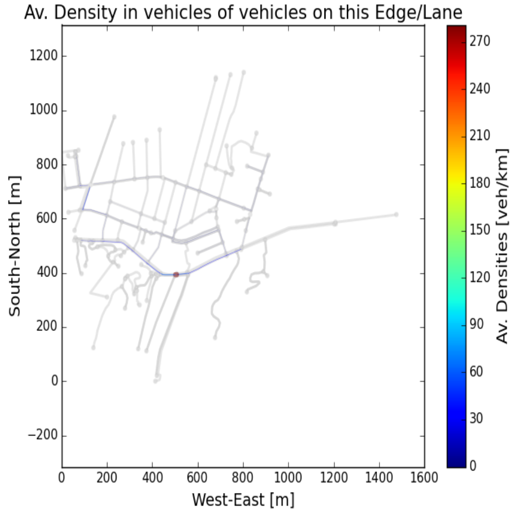

Figure 55: Density in vehicle of vehicles on this edge/ lane

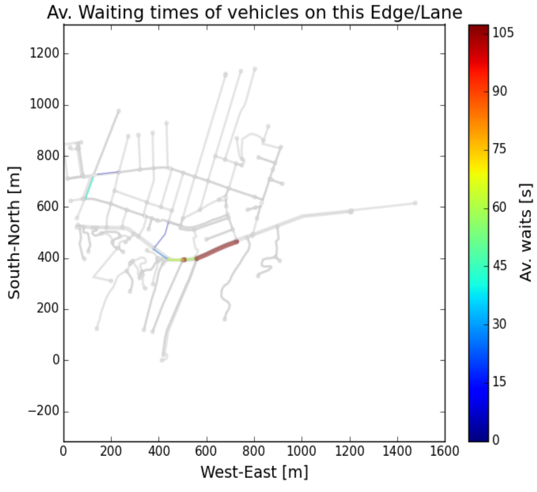

Figure 56: Av. waiting times of vehicle on this edge/ lane

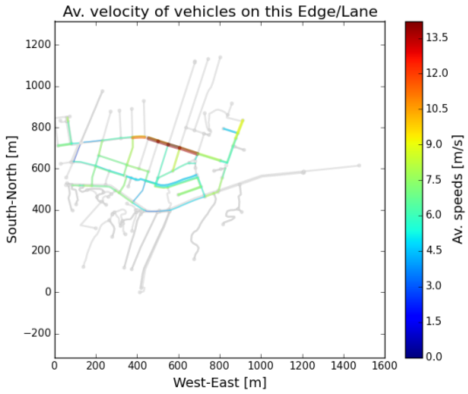

Figure 57: Av. velocity of vehicle on this edge/ lane

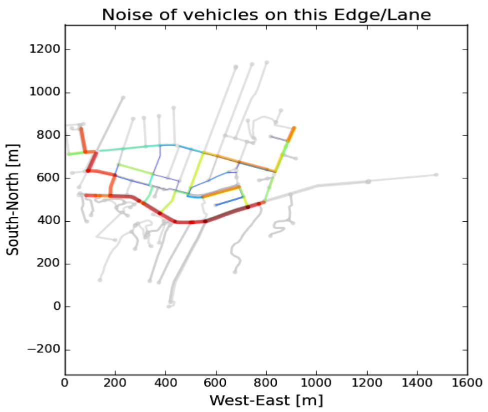

Figure 58: Noise of vehicle on this edge/lane

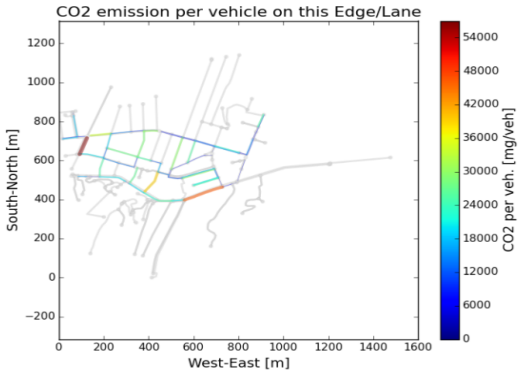

Figure 59: CO2 emission per vehicle on this edge/lane

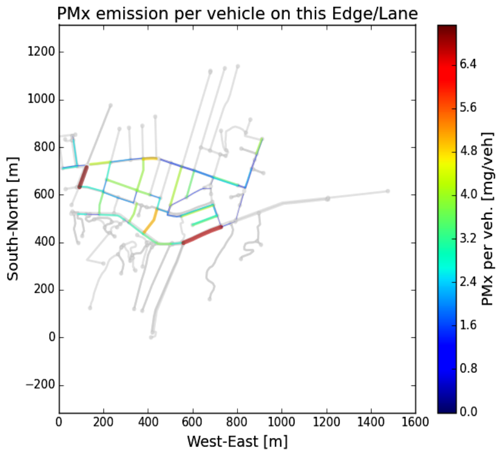

Figure 60: CO emission per vehicle on this edge/lane

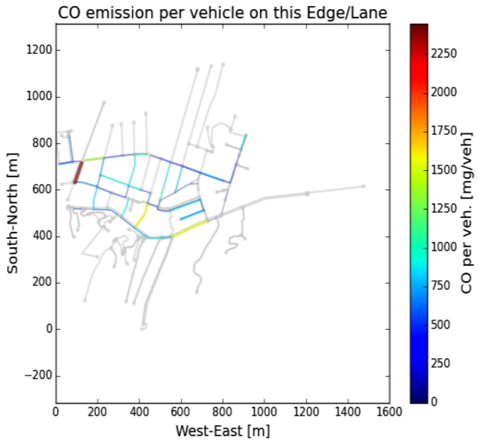

Figure 61: NOx emission per vehicle on this edge/lane

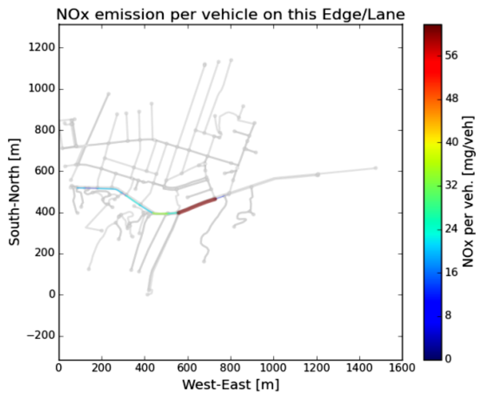

Figure 62: PMx emission per vehicle on this edge/lane

- **Edge data for proposing new bypass flyover**

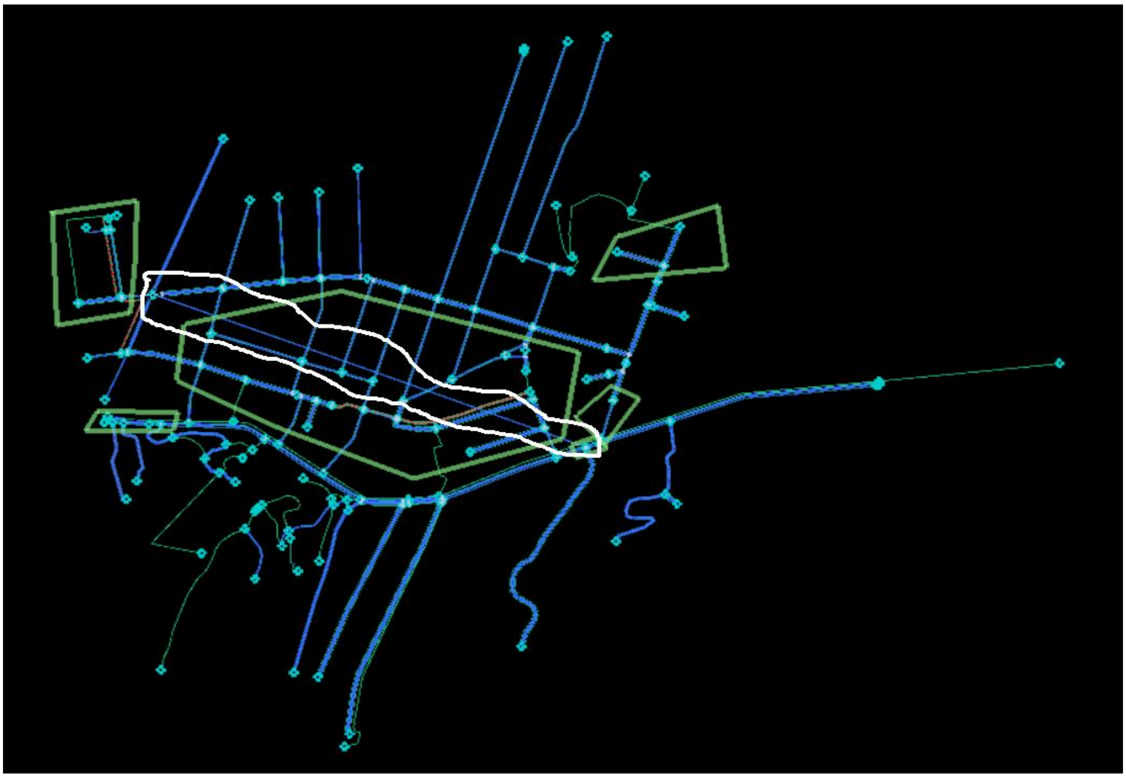

Figure 63

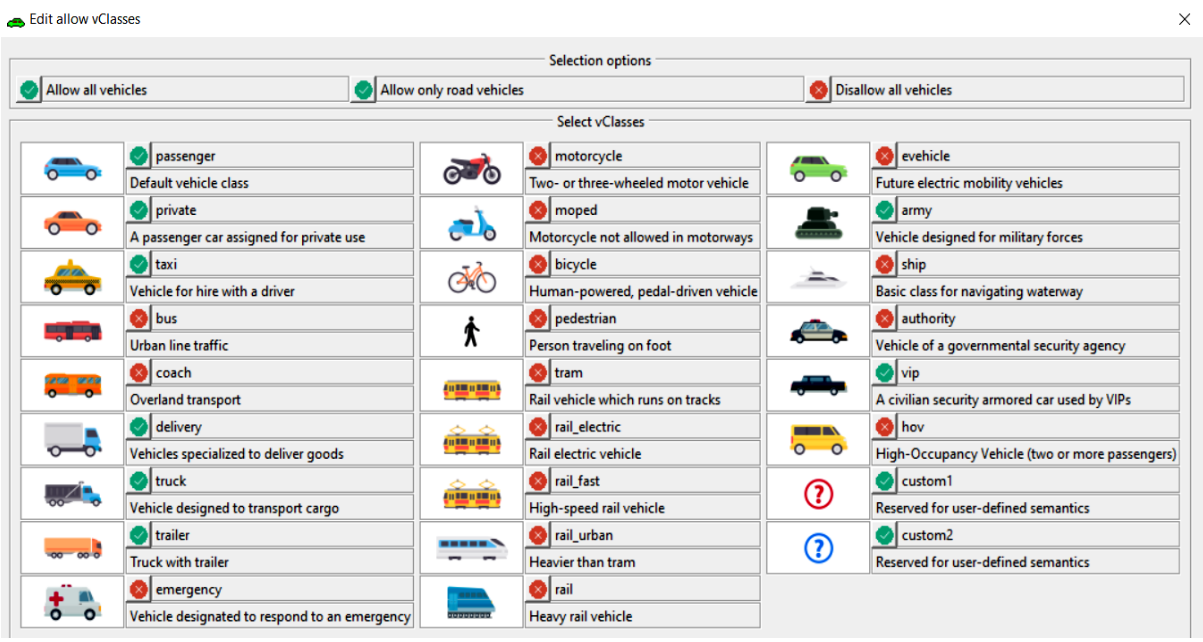

Figure 64

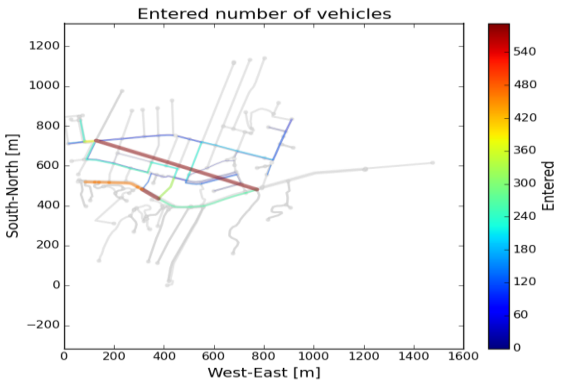

Figure 65: Entered no. of vehicles

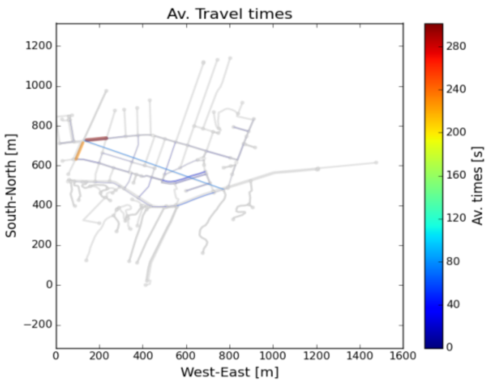

Figure 66: Av. Travel times

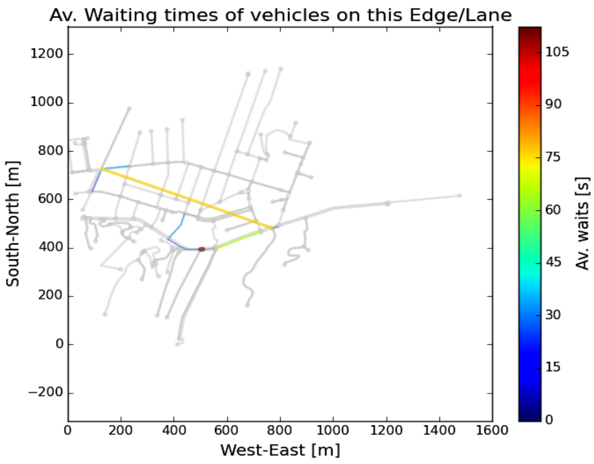

Figure 67: Av. waiting time of vehicle on edge/ lane

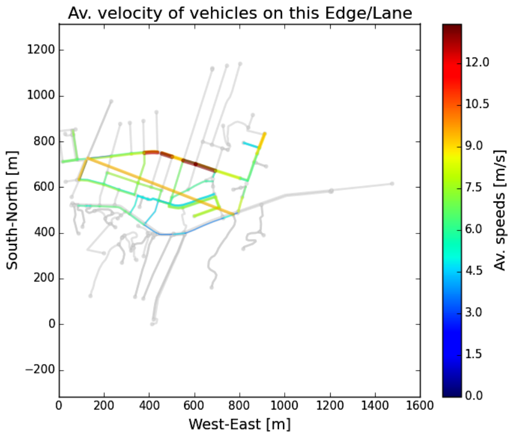

Figure 68: Av. velocity of vehicles on edge/ lane

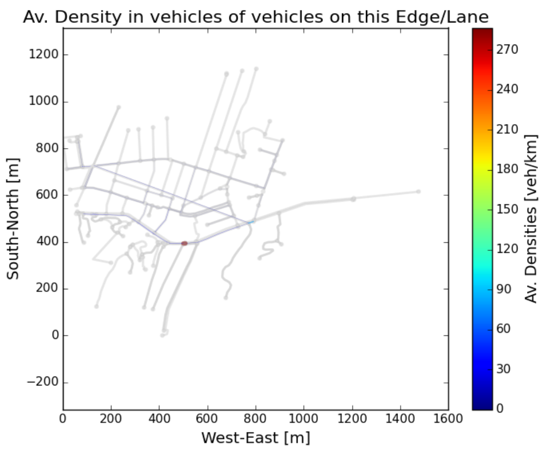

Figure 69: Density in veh. of vehicles on edge/ lane

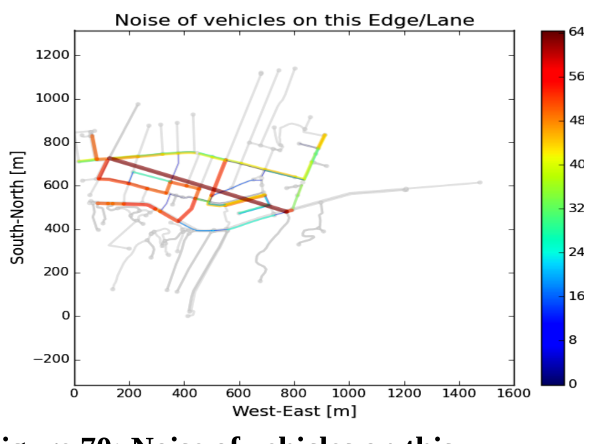

Figure 70: Noise of vehicles on this edge/ lane

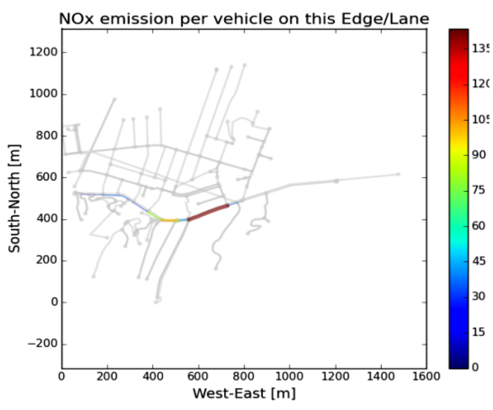

Figure 71: NOx emissions per vehicle on this edge/lane

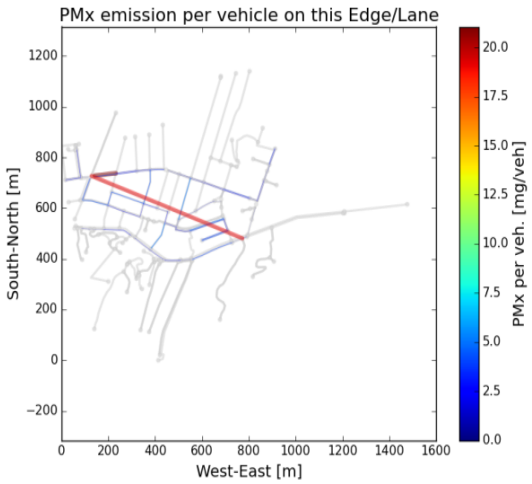

Figure 72: PMx emissions per vehicle on this edge/lane

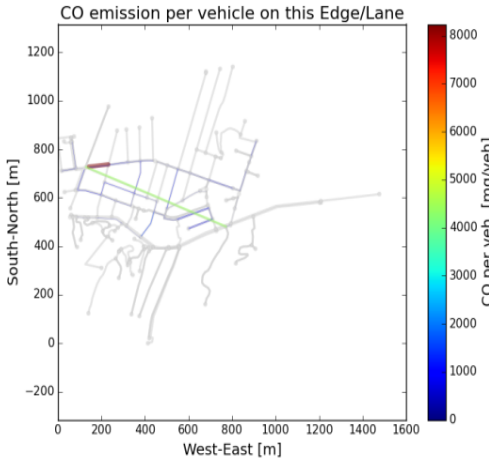

Figure 73: CO emissions per vehicle on this edge/ lane

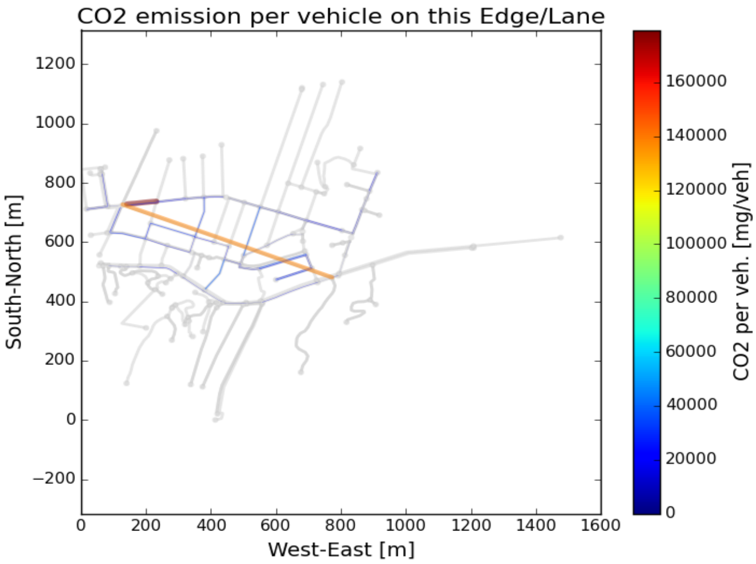

Figure 74: CO2 emissions per vehicle on this edge/ lane

SUMOPy Data Output Evaluation and Comparison					
SL. No.	**Major Edge Activity Name**	**Base Scenario Results**	**Future Scenario Results**		
			Window Hour With Restriction Of Speeds And Route Diversion	**Promote Green Transportation**	**Proposing New Bypass**
1	**Av. times [s]**	1236.631	1853.171	1246.056	1706.919
2	**Av. Densities [veh/km]**	1195.001	1267.549	1189.974	1137.220
3	**Av. waits [s]**	465.020	376.453	435.204	423.152
4	**Av. speeds [m/s]**	615.972	609.662	627.869	632.557
5	**Fuel per veh. [ml/veh]**	535.496	491.193	509.816	593.114
6	**CO per veh. [mg/veh]**	43057.103	37778.319	39933.022	45548.458
7	**CO2 per veh. [mg/veh]**	1223362.380	1122734.014	1164865.084	1356026.316
8	**NOx per veh. [mg/veh]**	230.465	405.651	217.304	608.477
9	**PMx per veh. [mg/veh]**	172.034	162.935	166.137	195.322
10	**Noise [dB]**	2432.018	2445.184	2321.532	2682.022

Table 9: Sumopy data output evaluation and comparison

V. RECOMMENDATIONS AND CONCLUSIONS

The main goal of the project is to create an overall sustainable transportation network by alleviating the current abnormalities in the existing network. The creation of a sustainable transportation network can consider different structures, such as sufficiently convenient sidewalks and bicycle lanes, to reduce the walking and cycling distance between the starting point and the destination in the network as well as reduction in pollution.

Although the existing network is very good, there is still some room for improvement. There are many bicycle lanes and sidewalks with dead ends. In order to meet all these requirements, new bicycle lanes and walking paths that connect to the existing network have been introduced, and walking distances and cycling distances should be reduced, which will ultimately promote behavioural changes in the use of different vehicles. In addition, when designing these paths, possible damage control to the existing environment is also considered. Likewise, existing obstacles in the path have been removed, and narrow circles can be enlarged.

We have introduced all the above parameters in micro simulation software named as SUMOPy, where we have improved the exciting network by increasing the bicycle paths and pedestrian paths. By comparing the results of exciting and redesigned network in the micro simulation we have obtained less pollution and the behavior of the passengers changed (moved from car to bicycles). Eventually, the final design of the proposed transportation network should fill the gap in providing a sustainable transportation network system.

Based on the observed results (refer Table 6) and review of relevant data, it is recommended to adopt **WINDOW HOUR WITH RESTRICTION OF SPEEDS AND ROUTE DIVERSION**, because following advantages are there as per the seriatim.

1. It is very easy to execute and requires simple tools/ equipment.
2. Comparatively lesser cost at around ten times the cost for other proposed schemes such as NEW BYPASS FLYOVER, as for executing a NEW BYPASS FLYOVER, there will be huge cost implications along with it will be too difficult acquiesce land for a NEW BYPASS FLYOVER for an existing developed city.

However, we also recommend PROMOTING GREEN TRANSPORTATION system, as it has less cost impact than other two proposals as mentioned above, and it will also create **less Noise,** if we will adopt public vehicle (Bus etc.) instead of personal vehicle (Car etc.) and use bicycle (it may be manual or electrically operated and environment friendly) instead of Motor Bike.

Ethics declarations: Conflict of interest: Both the authors state that there is no conflict of interest.

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